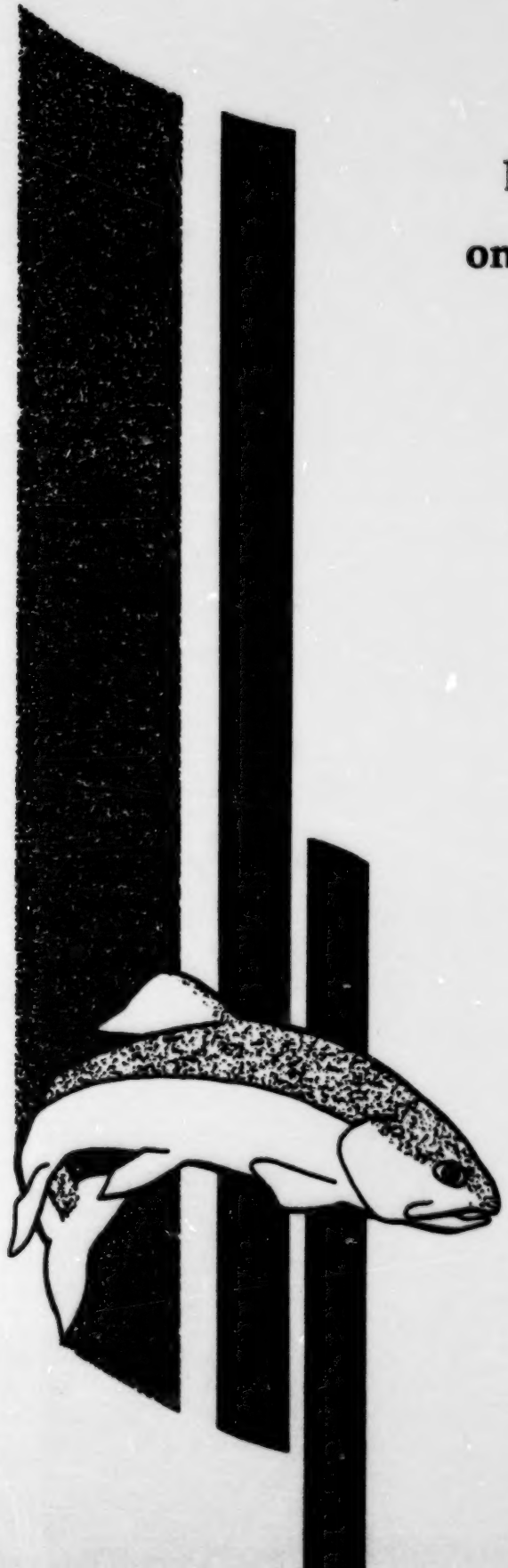

Long Term Data Collection on Kokanee from Large Lakes: Does It Make Sense?

by

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LONG TERM DATA COLLECTION ON KOKANEE FROM LARGE LAKES: DOES IT MAKE SENSE?

by

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Abstract

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A fishery manager needs data on individual stocks to: identify and understand the causes of fisheries problems, evaluate potential solutions and ensure continued support by documenting progress.

The goals of management define the data needs. In the case of kokanee management, I have assumed that the goals are to maintain or increase both angler effort and the quality of the angling experience while preserving fish stocks for the future. A basic data collection program should include indices of effort, fish size and angler CPUE to provide information on the fishery, and indices of fish density, growth rate and age at maturity to document the effects of management actions on fish populations. Decisions on specific actions including fishery regulation, habitat improvement or fish culture should not be made without the information necessary to guide those decisions.

The value of the fishery was used as a starting point for estimating a "reasonable" cost for a data collection program. For Kootenay and Okanagan lakes the value of each fishery is about $1,000,000 per year. In some commercial fisheries, management costs are about 30% of the value of the fishery. In addition, modest gains of 10% to 20% in yield and effort can be expected under an improved management regime. Expenditures of $50,000 to $100,000 per year therefore appear to be reasonable and are more than adequate for a basic data collection program.

Trawl and echosounding data from Kootenay and Okanagan lakes are summarized in an appendix as an example of the initial data points in a time series. Length and weight at age, length frequency distributions, age composition, catch per unit effort, spatial and temporal variation in density, and total population data are presented in a series of graphs and tables. Information on the fishery (boat counts, angler CPUE, fish size) is not included in this report but will be incorporated into future summaries.

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RATIONALE

The purpose of this report is to document the rationale and methodology for systematic data collection in the management of kokanee fisheries on large lakes.

The ultimate task of a fisheries manager is to make decisions on actions that will maintain or increase both angling effort and the quality of the angling experience. Much of a biologist's time is spent in the implementation of a variety of management techniques (eg. regulation of the fishery, fish culture, habitat protection/improvement) but, to make the initial decision on what action to take, a manager must have information. Long term, systematic data collection, especially the use of time series, is an essential part of this process.

Deterioration of a fishery (declining growth, population collapse) cannot be detected without at least a rudimentary data set. High quality data is important, both in detecting the early signs of deterioration, as well as in convincing the parties involved (ie. conflicting user groups, industries responsible for environmental degradation) of the reality of the problem. The current controversy over the state of chinook stocks in southwestern British Columbia (Frew 1988) is an example of both the value of time series in demonstrating a problem and the conflicting opinions created by an incomplete data set.

Time series are also essential in evaluating the success (or lack of success) of restoration and enhancement programs. In this case, inadequate data can result in an ineffective evaluation program (eg. Trautmann et al. 1982). Successful techniques may be discarded as useless while ineffective techniques remain in use.

Variation in natural and anthropogenic influences takes place on both short (annual) and long (decades) time scales and can result in large variations in growth and demographic features of various fish species. Examples of the effects of short and long term variability include: the influence of annual variation in summer water temperature on recruitment in alewives (Henderson and Brown 1985) and the influence of long term (~20 yr) cycles in water temperature and water level on the growth of lake whitefish (Reckahn 1986) in South Bay, Lake Huron. Without an appreciation of the long term natural variation in a fishery, managers may experience pressure to deal with fluctuations in abundance or size that are part of the normal variation within the population.

At a higher level, time series of fisheries data also contribute to our general understanding of the processes affecting fish populations. When faced with an event such as a recruitment failure, a manager needs to know whether past recruitment failures have been associated with uncontrollable factors such as water temperature or whether a more manageable factor such as over-exploitation may be involved.

Finally, data from time series is useful in the political arena both in justifying the need for controversial management action, as well as in maintaining the funding for successful management programs.

CHOOSING THE DATA SET

General Considerations

In many sport fisheries, including those for kokanee, the main objective of management is to maintain or increase angler effort while maintaining or increasing angling quality (CPUE, fish size) and preserving stocks for the future. Other objectives (eg. maximizing yield) are more appropriate for commercial fisheries where the catch is sold by weight.

In this context, indices of angling quality and, especially, angling effort are the key indicators of the success of a management program. Anglers vote via their participation. A sustained increase in angler participation, controlled for long term trends in regional angler effort, suggests that anglers are satisfied with changes in angling quality. Problems in interpretation can arise when there is a lag between a change in quality and the corresponding decline in effort. In many cases, an uncontrolled increase in effort results in a rapid decline in quality. The corresponding decline in effort may be delayed by a few years and may also be masked by regional increases in effort.

On the biological side, managers can affect angling quality by using various techniques (habitat protection, stocking, regulations) which optimize kokanee density. Kokanee density affects angling quality in two ways. The direct effect is on CPUE. When densities of catchable fish increase, CPUE also rises. The indirect effect is on fish size. An increase in density tends to produce a decline in growth rate which in turn alters fish size directly, by decreasing size at age, and indirectly, by changing age of maturity.

The basic information base therefore includes six types of data collection. Indices of effort, CPUE and fish size convey information about fishery. Indices of density, growth rate and age of maturity gauge the reaction of the kokanee population to management actions.

Managers also try to maximize natural survival rate (predator control, spawning gravel improvement) in order to maximize the sustainable exploitation rate. In addition, yields can be increased in some situations by altering the basic productivity of the system using techniques such as fertilization or exotic species introduction. These options are not the focus of this data collection program.

Distinctive problems will also demand more specialized data sets. For example, egg to fry survival is essential in evaluating the performance of a spawning channel and diet information is useful in evaluating the introduction of an exotic food item. The basic data collection strategy should complement these more specialized data needs.

Specific Choices

A variety of details can dramatically change both the cost and usefulness of information. For example, trends in effort can be monitored using counts made from an airplane, a boat, a viewpoint or a boat launch. Counts can be spread throughout the season or concentrated in very narrow time strata (eg. mid day counts on weekends in June). Sampling intensity can vary from occasionally to continuously.

Considerations that affect the usefulness of data in making decisions include: bias, variability and choosing to use an index rather than an absolute estimate of a parameter. In time series, indices are almost as useful as absolute measurements because decisions are usually based more on changes though time rather than actual values. When monitoring effort, estimating the change between two points in time is generally more important than estimating the actual number of angler days. The same is true for all six of the basic data needs.

An unknown, but consistent, bias does not affect the usefulness of an index type of time series, but even minor changes in bias can result in misinterpretation. Angler CPUE is not a good index of fish abundance because changing gear types or expertise can alter the effectiveness of anglers. Weekend boat counts may not be a true reflection of trends in angling effort if angler use, through time, is shifting to weekdays.

Variability is usually recognized as a problem but its seriousness is often underestimated. Sample size requirements are proportional to the square of the standard deviation and small differences in the amount of variability can therefore lead to greatly increased costs.

Given these considerations, a basic data collection program has been outlined in Table 1. These choices are, to some extent, arbitrary. Reasons for specific choices, as well as some of the associated technical and interpretive problems, are discussed below. Regardless of choice, a key element in the successful collection of time series data is consistency between sampling periods.

Aerial boat counts, an index of angler effort, are preferred over counts made from the shore or another boat because the whole lake can be counted in a short period, thus reducing the

Table 1. A basic data collection program for kokanee management in the large lakes of southern B.C.

Data Collection Activity	Purpose
Aerial Boat Counts (Weekends only, Peak season)	A time series of long term trends in angler effort with a full census every five years - To permit the association of changes in effort with changes in the number of available fish - An easy index to monitor harvest rate
Partial Creel Census (Weekends only, Roving, Peak season)	To measure Angler CPUE, Fish Size in the creel, Age at Maturity - Full census every five years - To monitor the proportion of adults that spawn prior to reaching a recruitable size - Angler CPUE is an index of population size. Inconsistencies between CPUE and other population indices indicate a change in angler effectiveness or a change in recruitabilty of adults.
Trawl Series (5 nights, Early October)	To measure Trawl CPUE, Age Class Composition and Growth Rate - Trawl CPUE is an age specific population index - Age Class Composition can be used to breakdown the acoustic population estimate into age classes
Acoustic Population Estimate (Early October)	To provide a time series on population trends
Spawner Counts	To measure size at maturity and provide a time series of population trends - Age at Maturity will be measured if otoliths can be aged

probability of shifting biases. A narrow time strata has been chosen in order to reduce variability and a full census every 5 years can be used to correct shifts in effort between strata over the long term. Other advantages include minimal contract supervision and moderate costs (20 counts/year cost ~$3000). Possible problems include: poor estimates of the number of anglers/boat, counting boats that are not fishing, and the need for a reliable, consistent observer in the plane.

A partial, roving creel census was chosen to maximize both the number of interviews and fish measured each day. Other methods of angler contact (Log book programs, Derby monitoring) have much lower costs but also have an unacceptable risk of a change in bias. Age at maturity from the creel is a poor index of true age at maturity because fish that mature at small sizes are poorly represented in the fishery. This problem can be partially overcome by measuring size and, hopefully, age in the spawning run.

In estimating size at age, trawl catches are preferred over other methods of capture because all age classes are sampled and the gear is less selective, especially over small (<5 cm) size ranges. Sampling efficiency is poor for larger fish, but other types of samples (gillnet, creel) may have strong biases over very small size ranges. Two-cable trawling may improve efficiency by eliminating obstructions in front of the net. Spring samples are preferred over fall samples because growth rates are low in the spring. When measured in the fall, size at age values must be corrected to a standard date to avoid bias, especially in smaller fish. Fall samples are nevertheless recommended in order to complement echosounding sampling which must be done in the fall.

Length at age is probably the best indicator of rearing conditions for kokanee in a lake. Changes in lengths at age are, however, difficult to associate with specific causes because of the many factors involved and the correlative nature of the relationships. A density-dependant growth relationship is of particular interest to managers in setting appropriate kokanee densities for each lake. Density-dependant growth responses have been repeatedly demonstrated in sockeye (eg. Kyle et al. 1988) and are probably present in kokanee as well.

Age at maturity in kokanee can shift either suddenly (eg. Parkinson et al. 1977) or in a long term trend (eg. Bowler and Rieman 1981). Both size at capture and size at maturity data are therefore unreliable indicators of growth rate since changes in growth rate can be masked by changes in age at maturity and vice versa.

A secondary objective of trawl sampling is to provide an index of population size through trawl CPUE. Although both small and large fish may be underrepresented, these biases should be consistent from year to year and trends in the density of each age

class should be accurately reflected by trawl CPUE. Variability is high, particularly in catches of older fish which may average less than 2 fish per 45 minute trawl. At least 5 nights of trawling (30 hauls) are recommended. Oblique hauls provide a more consistent and representative sample than single depth hauls.

Acoustic estimation is an attractive population index for kokanee because their behavior makes them good echosounder targets. Kokanee are essentially the only species found in the pelagic zone of this type of lake; they are not in schools at night and they are not found in the bottom or surface layers where echosounders are ineffective. Fall is the best time for echosounding because: age 0 fry are fully recruited to the gear, all ages remain below the thermocline at night, and spatial variation in density seems to be minimal at this time of year. Because of the typically patchy distribution of migrating fish, echosounding should ideally be done after the current year's spawners have left the lake. High Mysis densities interfere with age 0+ kokanee detection by creating background noise which masks echoes from small fish. Uniform noise threshold levels are essential in maintaining the consistency of population estimates from year to year. At this time, echosounding cannot detect size distributions directly but total population estimates can be broken down into age classes using trawl data.

Bank or aerial counts of spawners give an indication of the performance of different stocks within the population. Population fluctuations in different stocks do not appear to be synchronized in either Kootenay (south arm vs. north arm) and Okanagan (stream vs. shore) lakes. Problems with counts made from either the air or the ground include variable observation bias (eg. different observers, variable water clarity), variable stream residence times, observation difficulties (eg. shore spawners, large streams) and difficulties in covering numerous small streams. Fence counts eliminate observation and residence time biases but are prohibitively expensive except when they are associated with fish culture activities. Fecundity, measured indirectly through fish size, is important in that potential egg deposition may be a more appropriate measure of population size than actual spawner numbers.

Some highly desirable types of data are difficult or even impossible to get. For example, age specific survival rates can be very useful but because they are difficult to obtain with any degree of accuracy I have excluded them from the preferred data set.

Kootenay and Okanagan lakes have been chosen as initial candidates for this program because of well-documented management problems and the value of their fisheries. Data collected by the Research Section on these lakes are summarized in Appendix 1.

COSTS AND BENEFITS

Cost effectiveness is difficult to assess because neither costs nor potential benefits are easily defined. Costs can vary widely due to the many different options that are available in terms of type and frequency of data collection. Benefits, such as an increased supply of larger fish are difficult to quantify because they depend on the reaction of the ecosystem to management strategies and the value that anglers place on the improvements. My approach is to estimate what is a "reasonable" amount to expend on a data collection program and then determine if this is sufficient to support the expenses of data collection.

About 50,000 angler days are expended on both Kootenay (Andrusak 1981) and Okanagan (Bull 1987) lakes and the fishery is therefore valued at about $1,000,000 per year, assuming a value of $20 per angler day (Stone 1988). Management costs for Canadian commercial fisheries are often a substantial fraction of the value of the fishery. In Pacific salmon management, for example, the annual operating budget is 32% of the landed value of the catch (Pearse 1982). On heavily stocked lakes managed for rainbow trout, stocking costs alone are often a smaller but still significant fraction of the value of the fishery. Stocking costs on six small interior lakes averaged $1.63 per angler day (Table 2) or about 8% of the value of the fishery. On Kootenay or Okanagan lakes, an annual expenditure of $50,000 to $100,000 to manage and maintain these fisheries therefore appears reasonable. Anglers even appear willing to bear these costs directly. The special license fee on Kootenay Lake raised about $35,000 in revenue in 1987 (H. Andrusak, per. comm.).

Table 2. Stocking costs per angler day for six lakes in the southern interior region of B.C. Little or no natural reproduction takes place in any of these lakes. Weights stocked are from the 1987 stocking list. Cost per kilogram was set at $40 based on the analysis of Nordstrom et al. 1978. Effort estimates were generated from spring and summer boat counts that were made after 1980.

Lake Name	Weight Stocked (kg)	Cost of Stocking	Effort (Angler-days/yr)	Cost/ angler-day
Lady King	17	$680	1790	$0.38
Pinaus	435	$17400	5880	$2.95
Jocko	68	$2720	8600	$0.31
Pass	117	$4680	2640	$1.77
Chimney	104	$4160	2090	$1.99
Dugan	190	$7600	3160	$2.40
			MEAN=	$1.63

Another way of arriving at a reasonable cost for a management program is to estimate the increase in the size of the fishery that could be achieved through better management. In the case of Kootenay or Okanagan lake, a relatively modest increase of 10% in the size of the fishery would be valued at about $100,000, but potential gains are hard to quantify. Current yields from Okanagan Lake are in the range of 1 - 1.5 kg/ha but an empirical estimate of potential yield of 3.0 kg/ha (using the methods of Ryder 1965) suggests that modest gains are possible. Costs of a full monitoring program are site- and situation-specific but, a breakdown of typical expenses suggests that costs should be less than $50,000 per year.

Acoustic Population Estimate	$8,000
Trawl Sampling	$5,000
Data Analysis	$6,000
Annual Reporting	$3,000
Angler Counts	$3,000
Angler Interviewing	$4,000
Monitoring Spawning Run	$15,000
	$44,000

CONCLUSION

The lesson from the past is that the status of a large lake is rarely stable for more than ten years and that few of the changes have been deliberately induced in a predictable, controlled manner by fisheries managers. In the last 30 years, major changes in Kootenay and Okanagan lakes include: changes in nutrient status, alterations in water level fluctuations, the introduction of mysis, destruction and deterioration of spawning areas, spawning channel construction, predatory rainbow enhancement and increasing exploitation. The story is similar on other large lake systems including: Lake Michigan (Eck and Wells 1987), Lake Superior (MacCallum and Selgeby 1987), Lake Erie (Hatch et al. 1987), Lake Ontario (Christie et al. 1987), Lake Simcoe (Evans and Waring 1987), Lake Washington (Eggers et al. 1979) and Pend Oreille Lake (Rieman and Bowler 1980). Note that, although some factors (eg. lamprey invasion) are common to a number of lakes, each situation is very distinctive.

We cannot accurately predict or control future change but we will have to be ready to document, explain and ameliorate both the expected and unexpected changes in lake status. Decisions on specific actions in areas such as fishery regulation, habitat improvement or fish culture should not be made without the information necessary to guide those decisions.

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APPENDIX 1. THE KOOTENAY AND OKANAGAN DATA COLLECTION PROGRAM

Introduction

The purpose of this appendix is to formally establish the initial data points in a time series designed to monitor the status of kokanee populations in Kootenay and Okanagan lakes. The initial data points in a time series are typically not very informative and this report is therefore mostly a summary of data. Useful time series usually consist of at least 10 to 20 yr of data and often include much longer data sets (eg. Christie and Spangler 1987).

It is extremely important that the set of data to be collected each year and the precise methodology for data collection be firmly established within the next year or two. Data types can be added to the annual agenda of data collection but deleting a type of data collection or alterating methodology can seriously compromise the value of the eventual time series.

Information on the fishery (boat counts, angler CPUE, fish size) is not included in this report but will be incorporated into future summaries.

Methods

Kokanee of all ages were captured in a midwater trawl (4.5 m square at the mouth and 11.25 m long) with mesh sizes ranging from 101 mm to 9 mm in the body with a zippered nylon bag on the cod end. An inner cone (mesh size 25 mm) open at the cod end retained larger fish which often attempted to escape during the final retrieval process. Towing speed ranged from .85 to .95 m/sec. Towing depth was determined by using the angle and length of the tow cable and was verified on one occasion with a depth sounder in another boat.

Two sampling strategies were used. From 1984 to 1986, each trawl was made at a single depth in a depth-stratified sampling scheme. In 1987, depth stratification was ignored and oblique trawls were made at various locations. This is the sampling scheme that will be used in future. In oblique trawls, the net is lowered to the bottom of the layer of fish shown on the echosounder and is then raised through the layer at the standard towing speed in a series of 5 m steps. Each 5 m step was fished for 8 min before the net was moved up one increment.

Kokanee were aged using a combination of scales and length frequency plots (Fig. 1). Almost no scales were read from age-0+ fish but most could be obviously aged from their length alone. Scales were read from almost all age-1+ and older fish. Annuli were narrow but clear on most scales. Length segregation of age classes greatly assisted in scale interpretation. Specific problems included: an apparent lack of an annulus in some

90-110 mm fish in 1987, the presence of 2 annuli in some 110-130 mm fish in 1987 in Okanagan Lake and an estimated error of approximately 20% in classifying age-2+ and age-3+ fish.

The growth rate index was the weight and length at age of kokanee from trawl samples taken on the new moon closest to October 1. Growth rates are high at this time of year, especially for age-0+ fish. Typically, an age-0+ kokanee may grow from 1.3 g on September 15 to 2.0 g on October 15. To facilitate comparisons between years, weights were corrected to October 1 using growth rate data from Odell Lake. In future, corrections will be done using samples taken on the new moons before and after October 1.

Methods for echosounder population estimates are described in Parkinson (1986). A Biosonics 105 echosounder was used to make the 1985 and 1986 estimates but a Furuno FM-22 echosounder was used for the 1984 Kootenay Lake estimate. The Biosonics 105 system will be used in future.

Results and Discussion

Growth

Length frequency plots usually resulted in good multimodal segregation of age-0+, 1+ and 2+ kokanee in both lakes but little segregation of age-2+ and 3+ kokanee in either lake (Fig. 1). Exceptions are the merging of the age-0+ and 1+ peaks in 1986 in Kootenay Lake (Fig. 1c) and the tendency toward bimodality for the age-1+ fish in 1987 in Okanagan Lake (Fig. 1g).

Samples taken in 1987 indicated that there was little variation in size between locations within a lake for: age-0+ kokanee in both Okanagan (Fig. 2a) and Kootenay lakes (Fig. 2b), age-1+ kokanee in Kootenay Lake (Fig. 3a), and age-2+ kokanee in both lakes (Fig. 3b). A trend toward smaller size at more southerly stations was present in age-1+ kokanee in Okanagan Lake (Fig. 3a).

Growth rates of kokanee were similar in the two lakes for their first two summers but Okanagan Lake kokanee grew faster than Kootenay Lake kokanee during their third summer (Fig. 4). Size at age was variable among years in both lakes, particularly amongst younger fish (Tables 1 and 2). Most of these differences are smaller when weights are standardized to October 1, but a recent increase in the size of age 1+ fish in Okanagan Lake is still obvious (Fig. 5). Comparisons of late fall and early spring weights at age (Fig. 5) suggests that younger fish are growing rapidly in late fall and substantiates the need for correction to a standard date in fall growth samples.

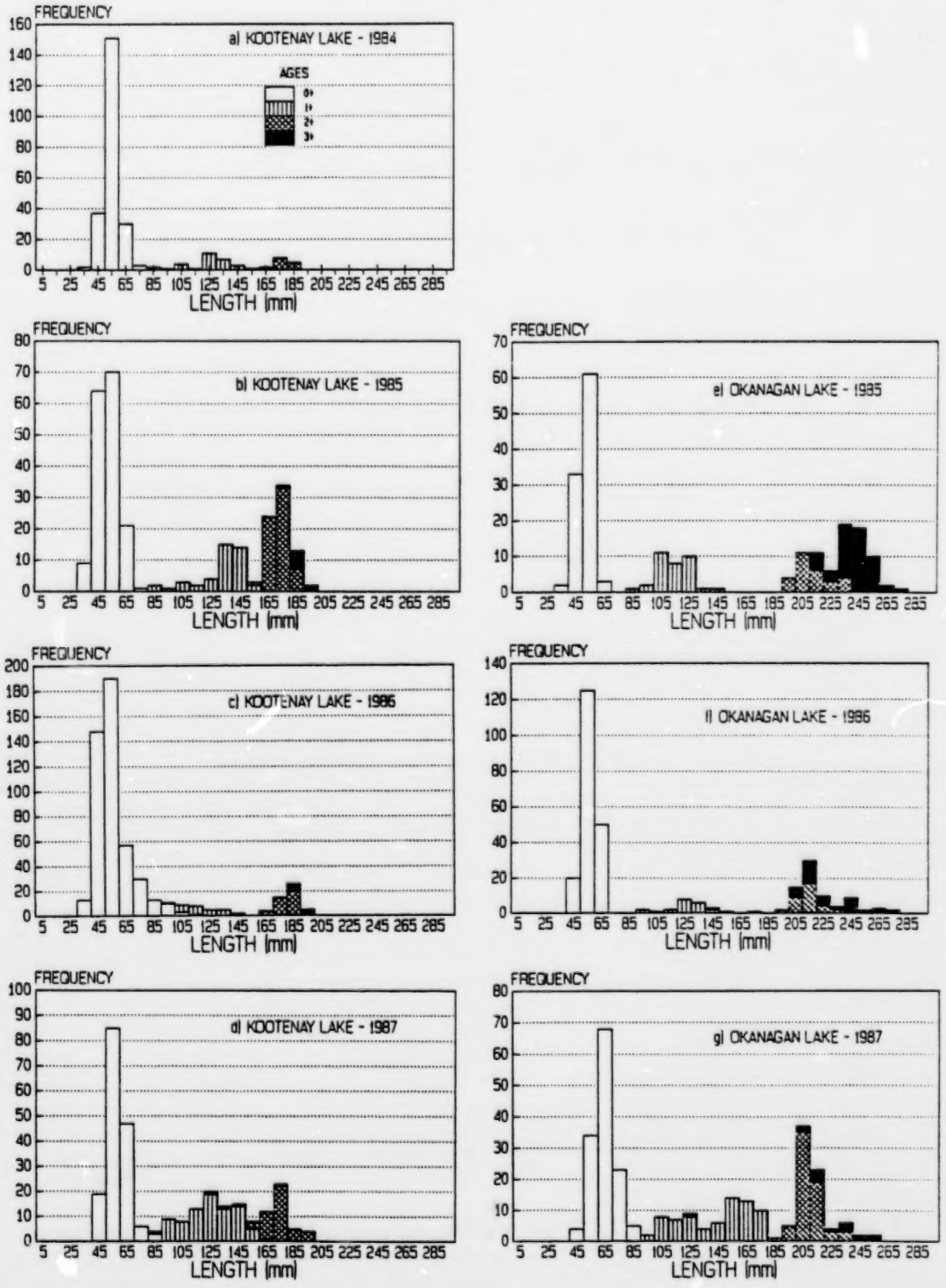

Figure 1. Length frequency distributions of kokanee in fall trawl catches from Kootenay and Okanagan lakes.

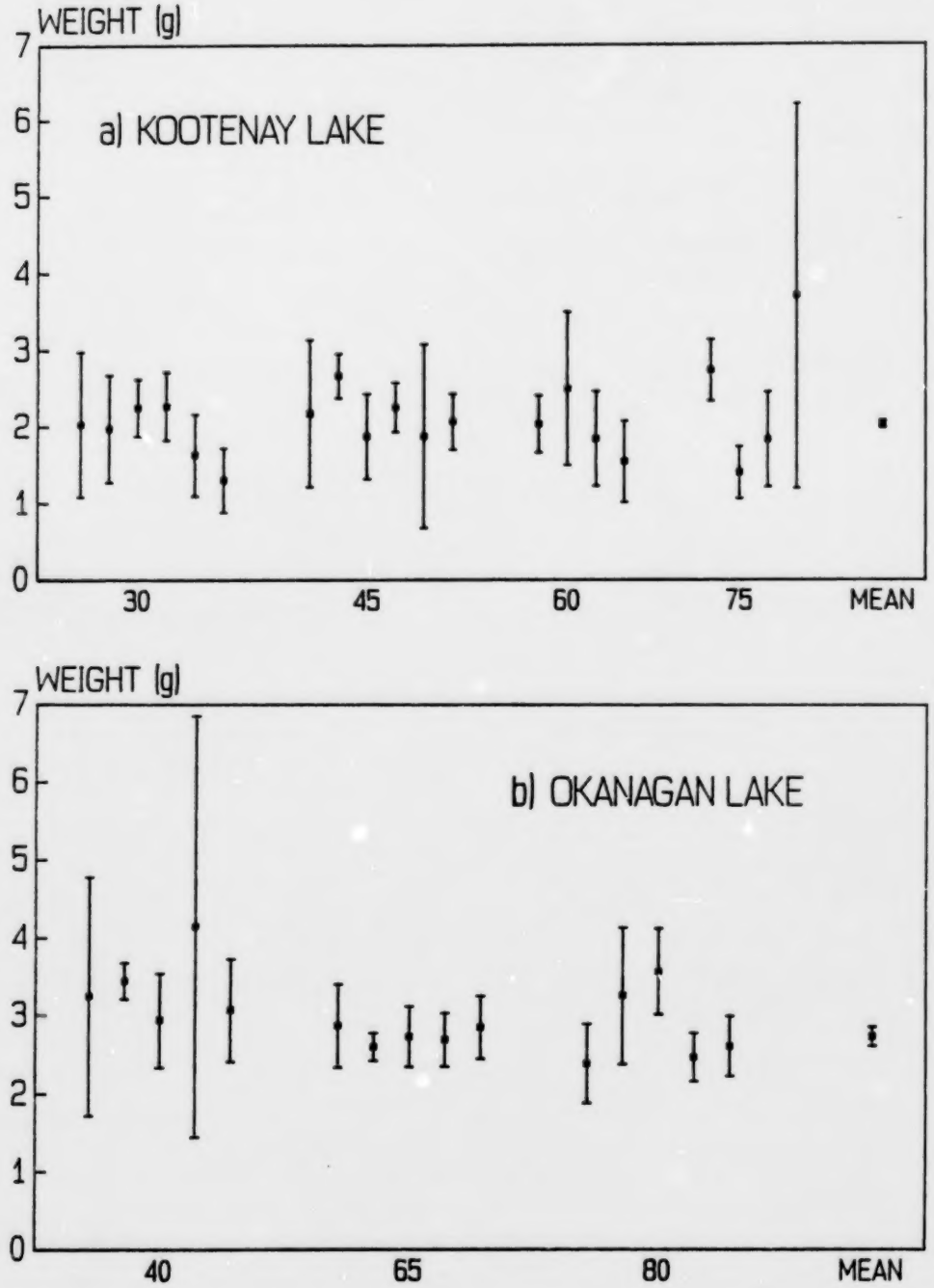

Figure 2. Spatial variation among stations for wet weights of age-0+ kokanee from Kootenay (N=160) and Okanagan (N=326) lakes in October 1987. Each bar represents the results of a single haul. Hauls are grouped by station. The number below each group is the station location given in terms of kilometers from the north end of the lake. Bars are ± 2 Standard Errors.

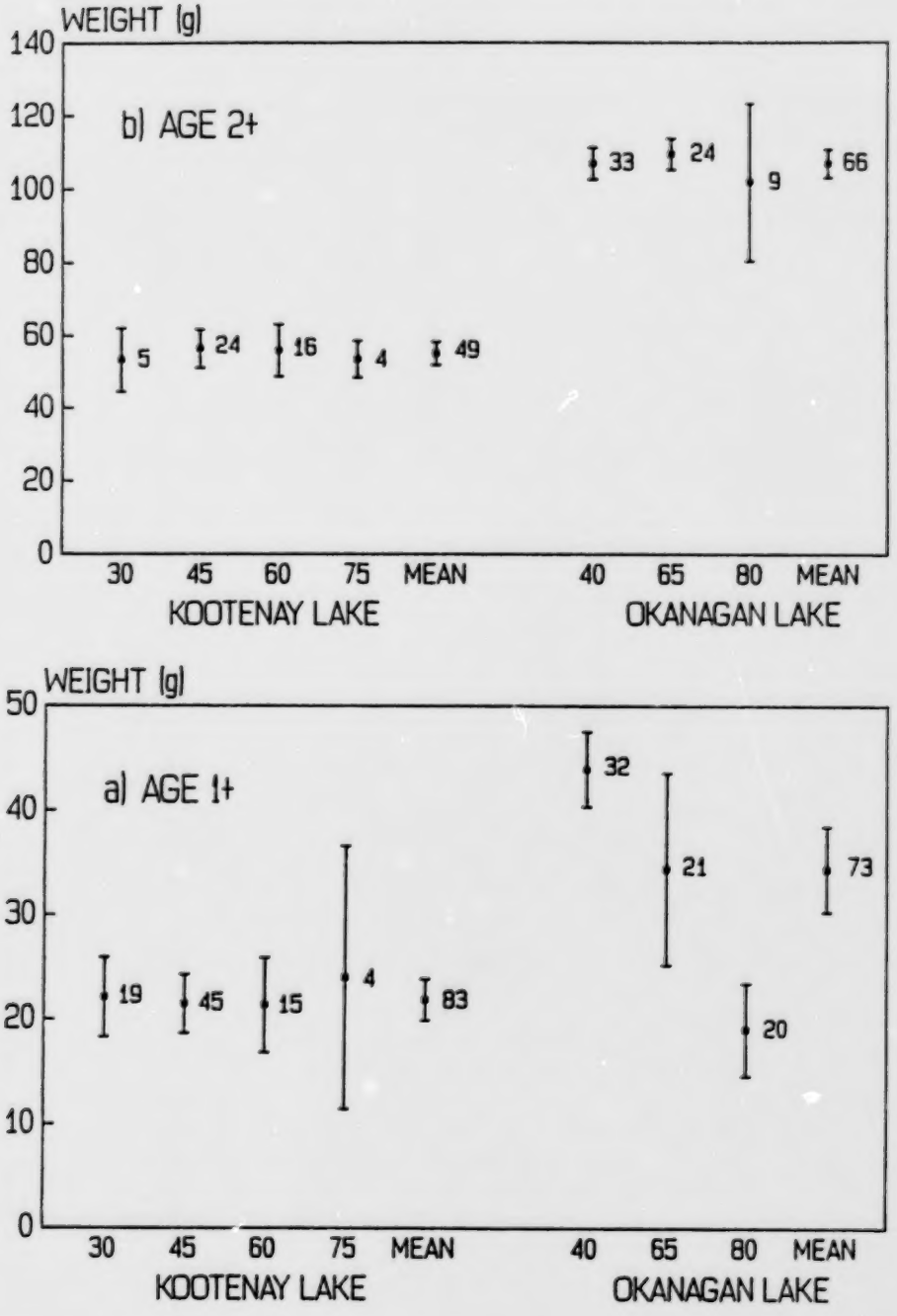

Figure 3. Spatial variation among stations for wet weights of age-1+ and age 2+ kokanee from Kootenay and Okanagan lakes in October 1987. Each bar represents the results of a 4 to 6 hauls at a single station. Numbers beside each mean are sample sizes. Numbers on the X-axis are station locations given in terms of kilometers from the north end of the lake. Bars are ± 2 S. E.

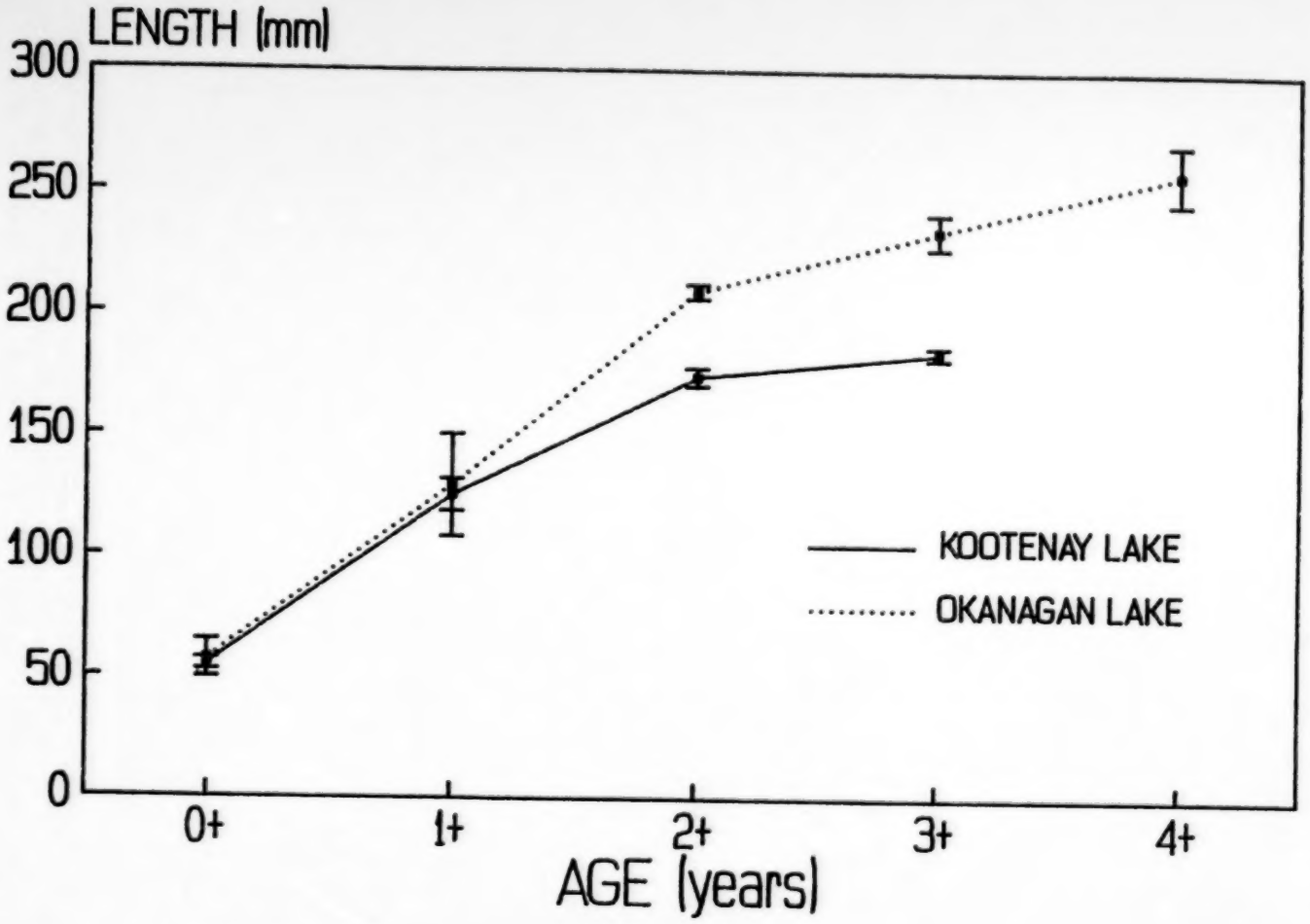

Figure 4. Growth curves for fall trawl samples of kokanee from Kootenay and Okanagan lakes. Bars are ± 2 S.E.

Table 1. Mean fork lengths and wet weights for kokanee in Kootenay Lake. Standard errors on averages for each age class are calculated using the variance among years.

AGE	YEAR	DATE	N	MEAN LENGTH	S.E.	N	MEAN WEIGHT	S.E.
FALL SAMPLES								
0	1984	Oct. 1	223	54.7	0.38	223	1.23	0.030
	1985	Oct. 8	168	51.8	0.70	168	1.48	0.077
	1986	Oct. 7	465	55.3	0.58	465	1.90	0.079
	1987	Oct. 18	160	57.7	0.59	160	2.03	0.077
	AVERAGE			54.9	1.21		1.66	0.185
1	1984	Oct. 1	29	122	2.87	29	15.5	1.01
	1985	Oct. 8	37	135	2.11	37	26.7	1.23
	1986	Oct. 7	26	120	2.73	26	17.9	1.35
	1987	Oct. 18	83	125	1.99	83	21.9	0.99
	AVERAGE			125	3.33		20.5	2.45
2	1984	Oct. 1	16	175	3.87	16	44.2	1.36
	1985	Oct. 8	69	170	1.15	69	52.5	0.90
	1986	Oct. 7	41	179	1.06	41	60.4	0.96
	1987	Oct. 18	49	173	2.66	49	55.0	1.61
	AVERAGE			174	1.89		53.0	3.37
3	1984	Oct. 1						
	1985	Oct. 8	8	184	1.68	8	66.2	1.37
	1986	Oct. 7	9	187	1.94	9	69.3	2.16
	1987	Oct. 18	1	182	0.00	1	65.7	0.00
	AVERAGE			184	1.26		67.1	0.98
SPRING SAMPLES								
1	1985		28	68.4	1.46	28	2.67	0.170
	1986		82	65.6	0.97	82	2.79	0.137
	1987		160	74.9	0.29	160	5.10	0.290
	AVERAGE			69.6	2.76		3.52	0.791
2	1985		38	136	1.49	38	21.6	0.66
	1986		31	140	2.60	31	29.1	1.51
	1987		39	127	0.90	39	20.9	0.90
	AVERAGE			134	3.84		23.9	2.63
3	1985		7	171	3.93	7	42.5	3.39
	1986		51	175	0.94	51	57.1	0.86
	1987		10	173	4.80	10	54.3	4.80
	AVERAGE			173	1.15		51.3	7.75

Table 2. Mean fork lengths and wet weights for kokanee in Okanagan Lake. Standard errors on averages for each age class are calculated using the variance among years.

AGE	YEAR	DATE	N	MEAN LENGTH	S.E.	N	MEAN WEIGHT	S.E.
FALL SAMPLES								
0	1985	Sept 15	99	51.2	0.55	99	1.26	0.040
	1986	Oct. 2	195	55.9	0.35	195	1.75	0.033
	1987	Oct. 16	151	64.4	0.65	343	2.77	0.059
	AVERAGE			57.2	3.86		1.90	0.423
1	1985	Sept 15	34	113	2.16	34	13.6	0.93
	1986	Oct. 2	22	125	3.12	22	20.6	1.70
	1987	Oct. 16	107	149	2.34	107	38.3	1.67
	AVERAGE			129	10.58		24.2	7.35
2	1985	Sept 15	28	211	2.44	28	115.0	4.84
	1986	Oct. 2	37	209	2.61	37	113.6	4.60
	1987	Oct. 16	103	206	1.25	103	104.2	1.56
	AVERAGE			209	1.45		110.9	3.39
3	1985	Sept 15	54	241	1.74	54	174.9	4.12
	1986	Oct. 2	43	229	3.03	43	154.2	6.88
	1987	Oct. 16	42	232	2.73	42	154.7	5.94
	AVERAGE			234	3.60		161.3	6.81
4	1985	Sept 15	3	258	3.79	3	217.1	10.14
	1986	Oct. 2	2	248	0.00	2	183.1	0.00
	1987	Oct. 16	2	269	0.00	2	234.4	0.00
	AVERAGE			258	6.07		211.5	15.07
SPRING SAMPLES								
1	1986		329	78.1	0.46	329	5.12	0.103
2	1986		40	131	3.43	40	25.1	2.00
3	1986		8	199	8.47	8	91	11.38
4	1986		4	230	7.95	4	138	12.70

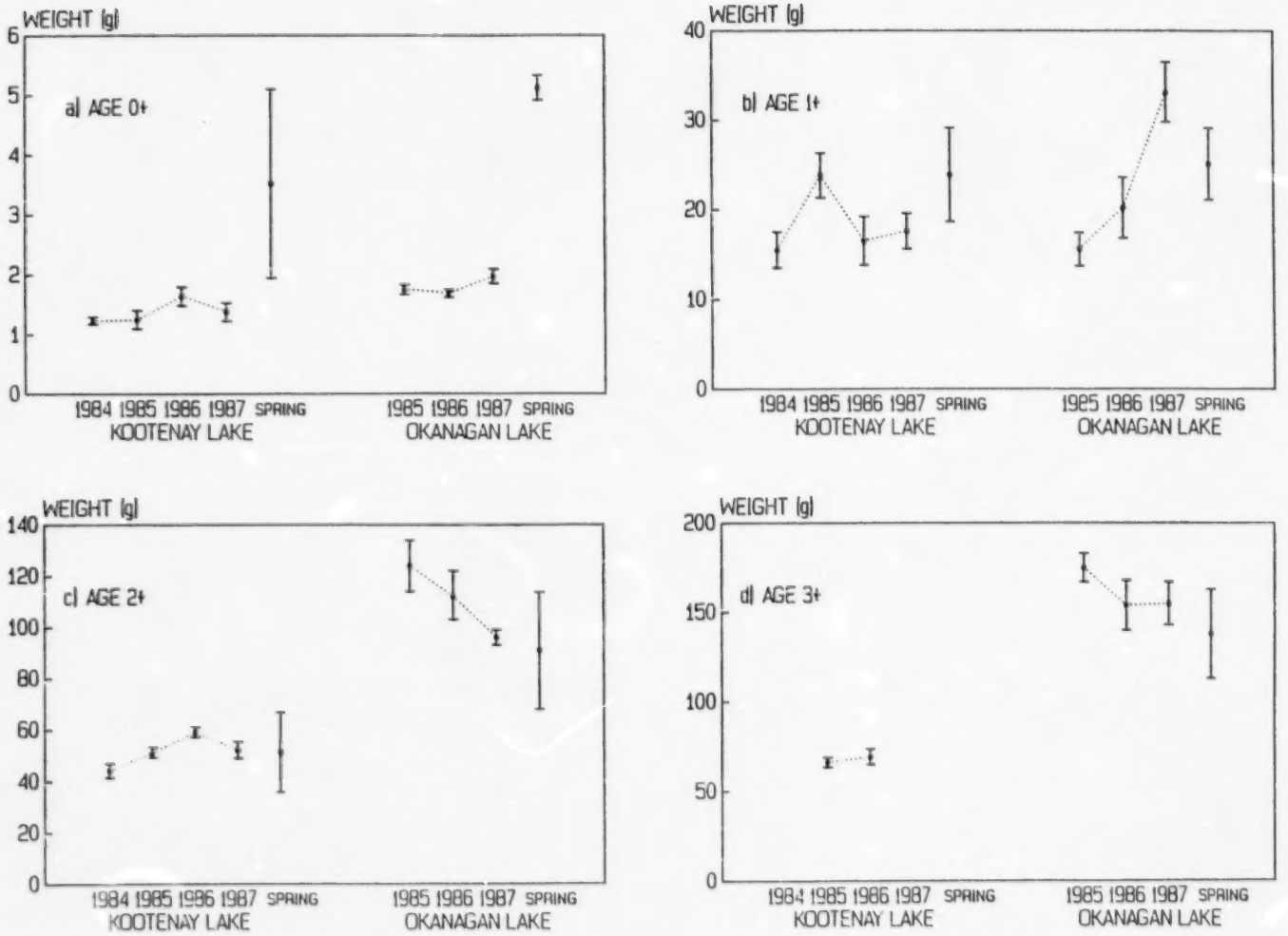

Figure 5. Variation among years in wet weights at age for fall trawl samples of kokanee from Kootenay and Okanagan lakes. Weights have been corrected to a standard date (October 1) using the estimated daily instantaneous growth rate for each age class. Weights for the same age kokanee taken in trawls in early March are included for comparison. Bars are ± 2 S.E.

Age Structure

Numerically, about 99% of trawl catches consisted of various age classes of kokanee but occasional burbot (Lota lota) pygmy whitefish (Prosopium coulteri) and peamouth chub (Mylocheilus caurinus) were also captured. Single Dolly Varden char (Salvelinus malma) and rainbow trout (Salmo gairdneri) were also captured in Kootenay Lake. Almost all non-kokanee were adults.

In both lakes, age structure varied significantly among years (Fig. 6), if all samples from a given year are pooled and binomial variances are used. Although variation in age structure between stations was small in Kootenay Lake (Fig. 7a), the large difference in age structure between the north (station 40) and south (stations 65 and 80) basins of Okanagan Lake (Fig. 7b) suggests that estimates of age structure based on pooled samples from a few stations may be unreliable.

Older fish were caught in deeper trawls in 1985 and 1986 both in Kootenay and Okanagan lakes (Fig. 8). This trend was less pronounced in Okanagan Lake in 1985 (Fig. 8b) when maturing age-3+ kokanee were caught at all depths. In 1986, most of the age-3+ kokanee were also maturing but were not captured in the shallower trawls. Only occasional kokanee were captured in night trawls at depths of less than 15 m in either lake.

Catch per Unit Effort (CPUE)

CPUE in oblique trawls differed among locations for all three age classes (Table 3, Fig. 9). CPUEs for age-0+ and age-2+ kokanee were nearly twice as high in Okanagan Lake as in Kootenay Lake but these differences were insignificant because of the high variability among locations and trawls within each lake.

Population Estimates

Fish densities estimated by the echosounder were assumed to be equivalent to kokanee densities since trawl samples indicated that essentially all pelagic fish were kokanee.

Kokanee densities typically varied about 3- to 4-fold between transects within a lake within a year (Fig. 10). The large variances of these density estimates imply that only large (2-fold) differences are significant but formal analysis is difficult because of the unusual nature of echosounding data. The pattern of density variation was consistent between years in Okanagan Lake but not in Kootenay Lake (Fig. 11).

Total population estimates were higher in 1986 than in 1985 in both lakes (Fig. 12). Mysis interference is a continuing problem on both lakes and further work will have to be done to ensure that population estimates are comparable between years.

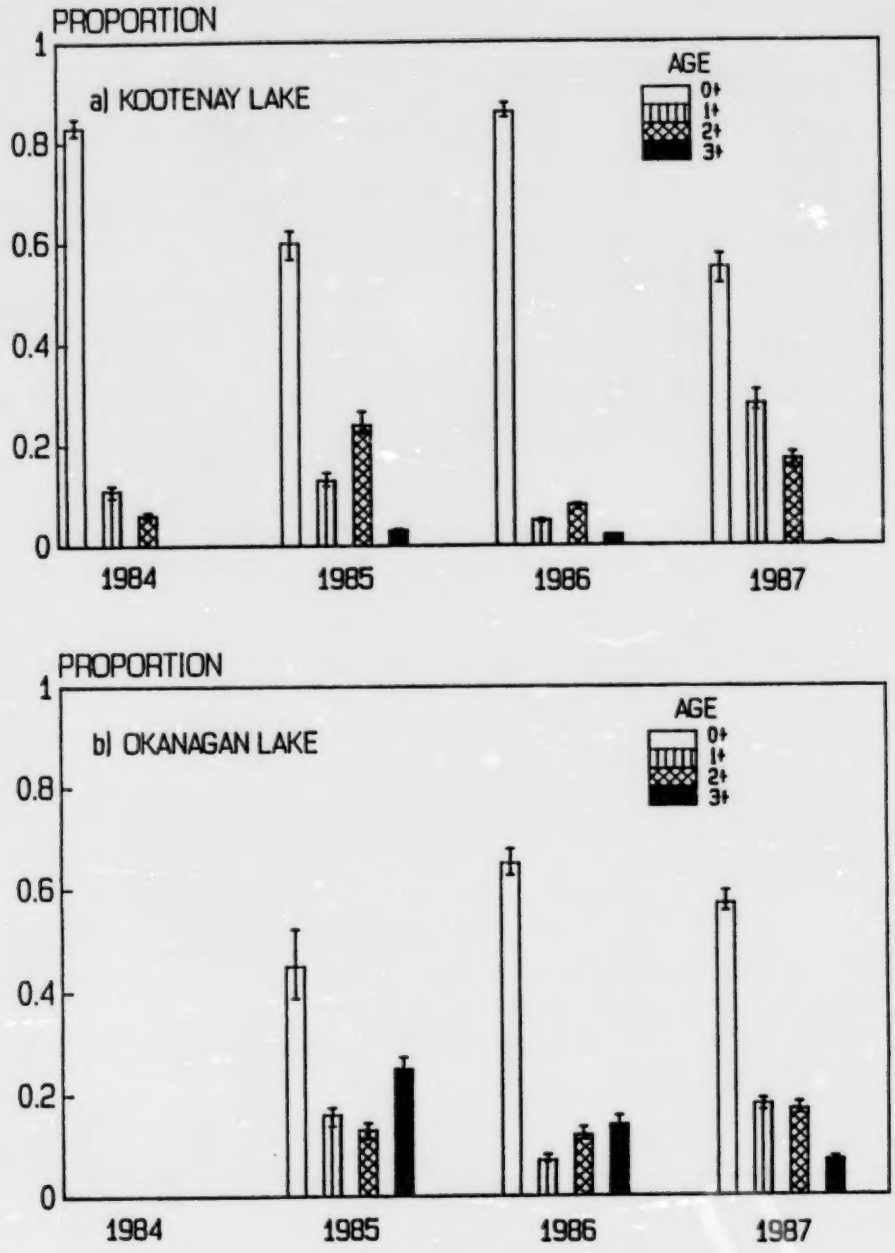

Figure 6. Annual variation in age structure of kokanee in fall trawls from Kootenay and Okanagan lakes. Range bars are 95% confidence limits calculated using $\pm$ 1.96 $(p(1-p)/N)^{1/2}$ where p is the proportion in an age class and N is the total number of fish captured that year.

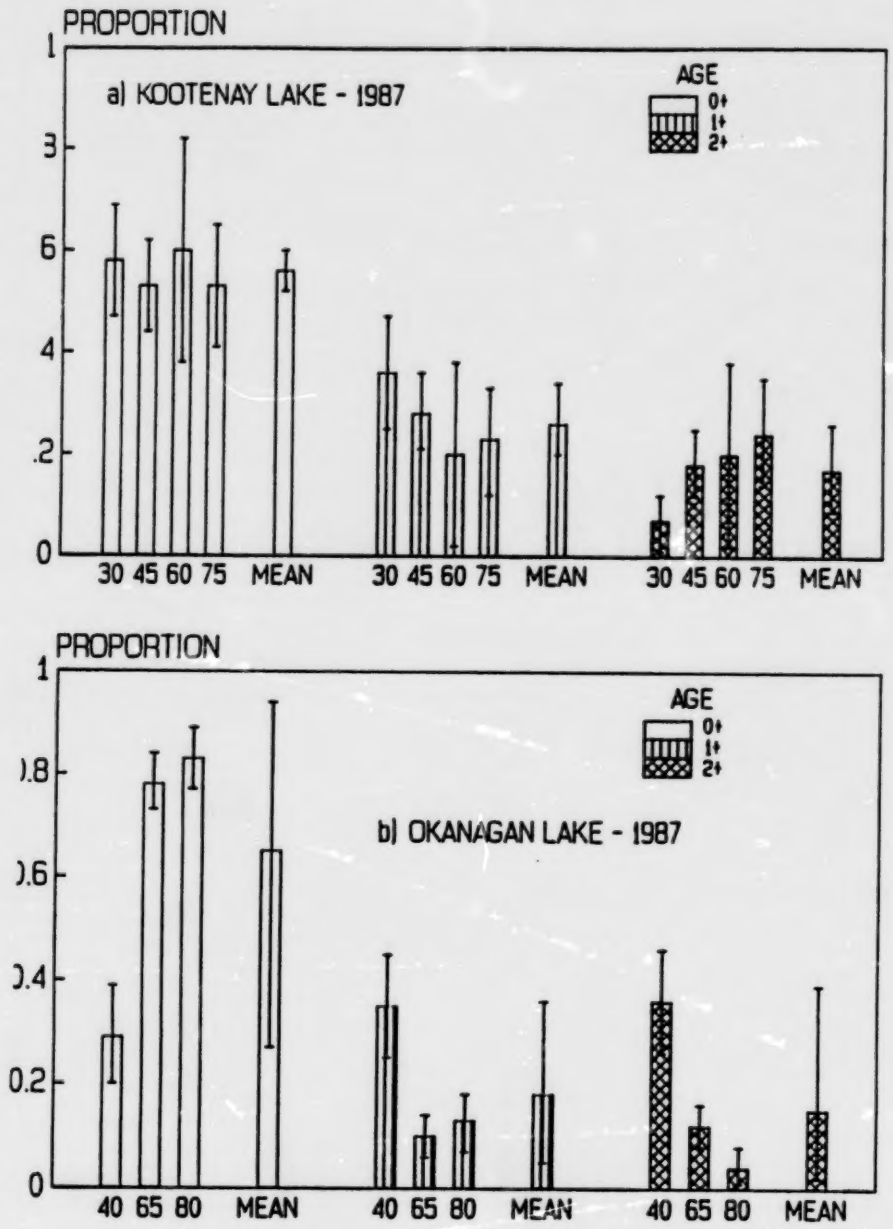

Figure 7. Variation among stations in the proportions of each age class in the 1987 trawls from Kootenay and Okanagan Lakes. Numbers on the X-axis are station locations given in terms of kilometers from the north end of the lake. Range bars for each station are 95% confidence limits calculated using $\pm$ 1.96 $(p(1-p)/n)^{1/2}$ where n is the number of fish captured at each station. Range bars for the means are 95% confidence limits calculated from the variance of the arcsine square root transformed proportions from each station.

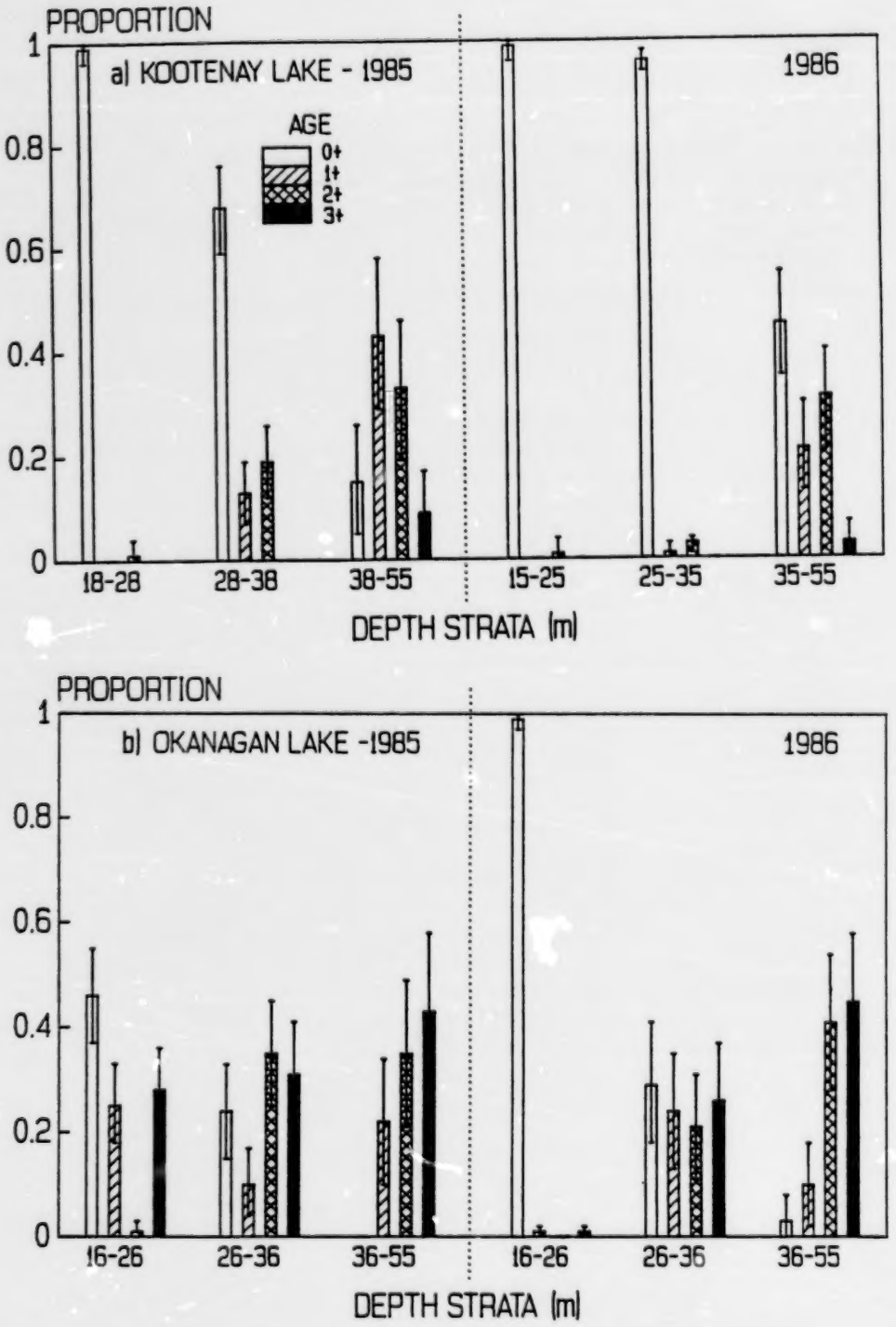

Figure 8. Proportions of each age class of kokanee in depth stratified trawls made in Kootenay and Okanagan lakes in the fall of 1985 and 1986. Range bars are 95% confidence limits calculated using $\pm$ 1.96 $(p(1-p)/n)^{1/2}$ where n is the number of fish captured at each depth.

Table 3. Summary tables for nested ANOVAs of CPUE in the 1987 oblique trawls for age-0+, age-1+ and age-2+ kokanee in Okanagan and Kootenay lakes. A square root transformation was used on the raw data. Figure 9 gives means at various levels.

Age-0+ Variation in CPUE

SOURCE of VARIATION	df	SS	MS	F	
LAKE	1	19.79	19.79	2.734	N.S.
STATION	5	36.20	7.24	5.752	**
WITHIN	28	35.24	1.26		
TOTAL	34	91.23			

Age-1+ Variation in CPUE

SOURCE of VARIATION	df	SS	MS	F	
LAKE	1	0.38	0.38	0.375	N.S.
LOCATION	5	5.08	1.02	2.339	p~.07
WITHIN	28	12.17	0.43		
TOTAL	34	17.63			

Age-2+ Variation in CPUE

SOURCE of VARIATION	df	SS	MS	F	
LAKE	1	1.74	1.74	0.901	N.S.
LOCATION	5	9.68	1.94	6.676	**
WITHIN	28	8.12	0.29		
TOTAL	34	19.54			

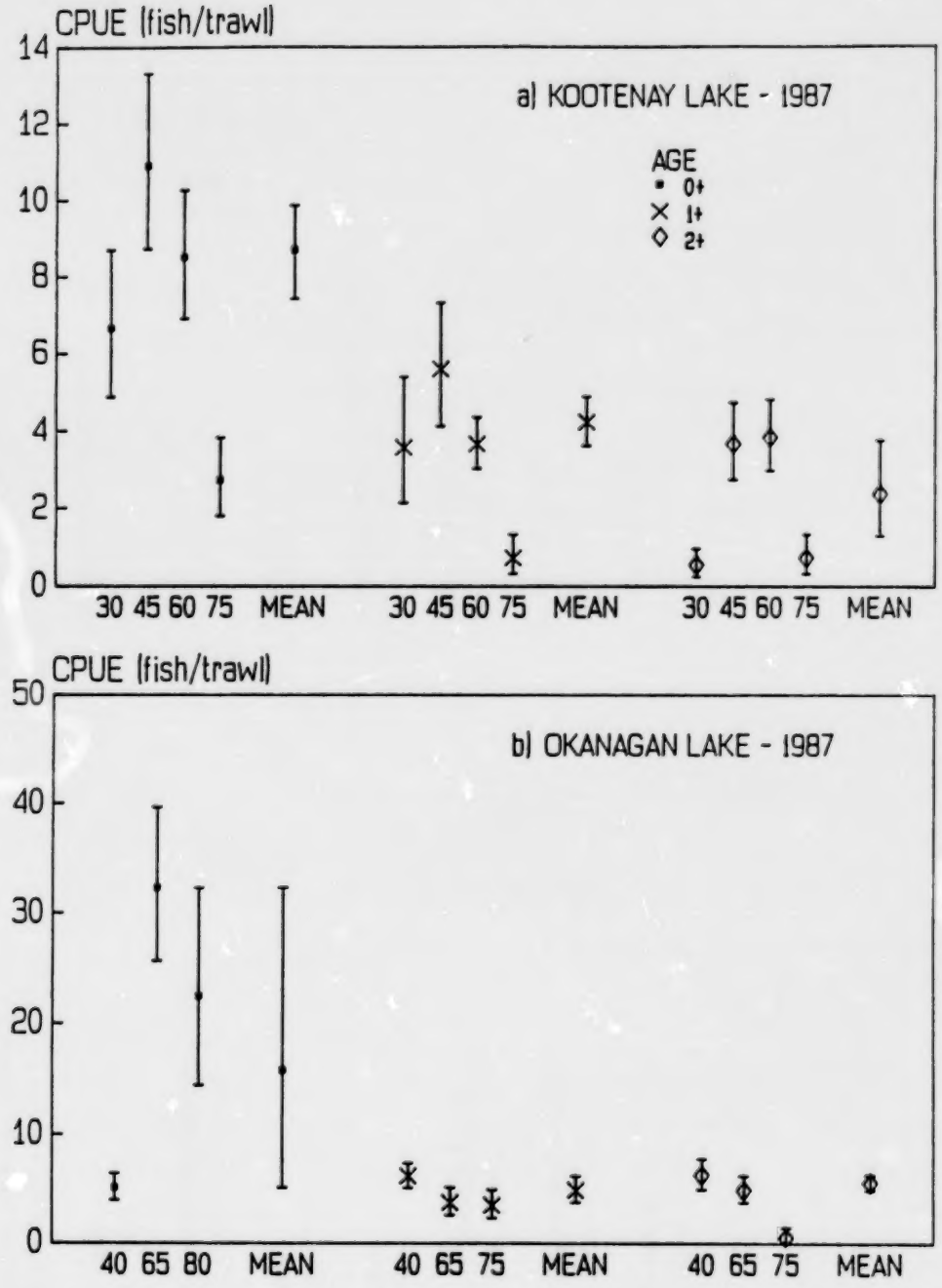

Figure 9. Catch per unit effort (CPUE) for oblique, standardized trawls made in Kootenay and Okanagan lakes in the fall of 1987. Numbers on the X-axis are station locations given in terms of kilometers from the north end of the lake. Range bars for each station are ± 1 S.E. The number of trawls per station ranges from 4-6. Range bars for the means are ± 1 S.E. calculated from the variance of the station means. A square root transformation was used on the raw data.

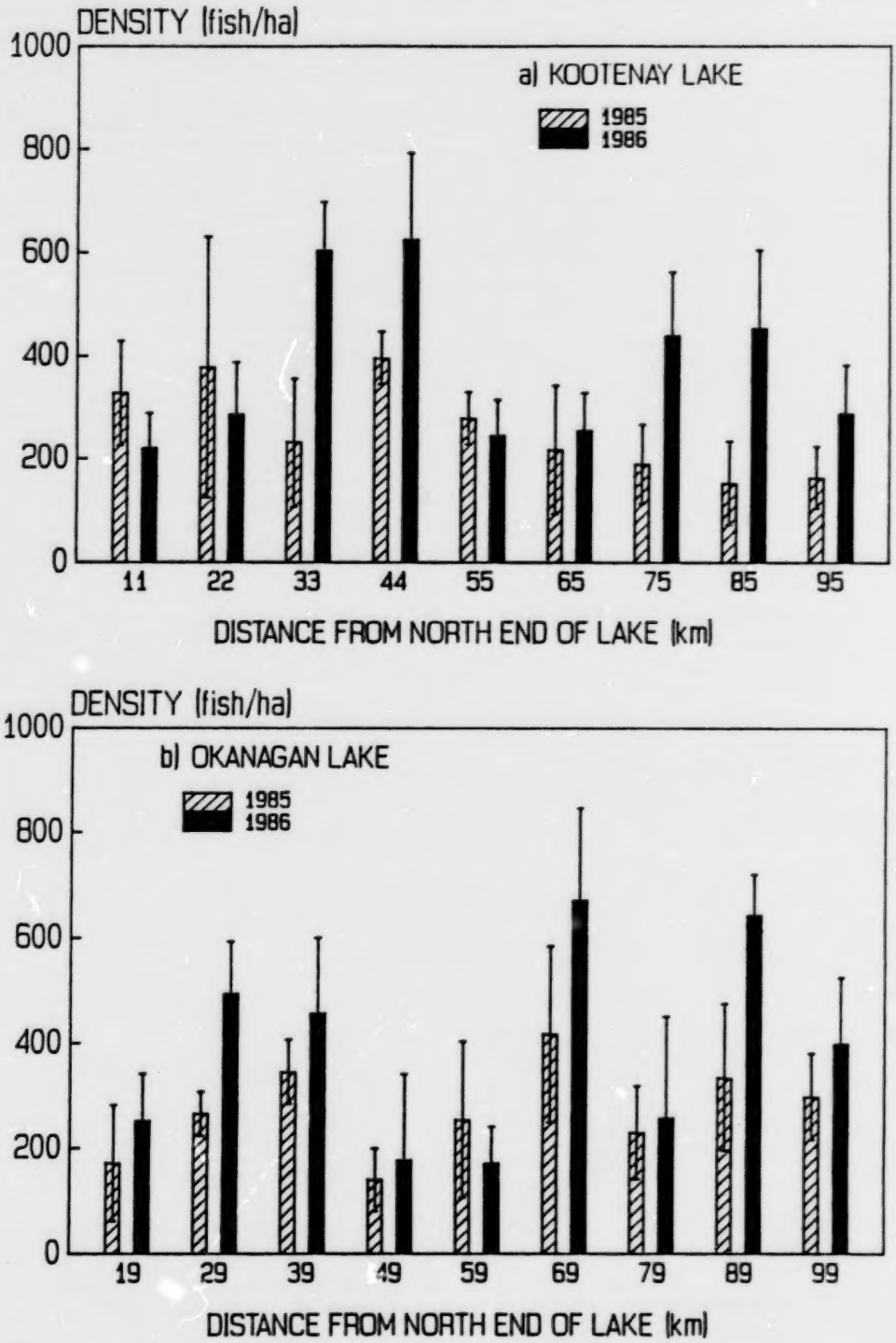

Figure 10. Kokanee densities at various locations in Kootenay and Okanagan lakes. Range bars are ± 2 S.E.

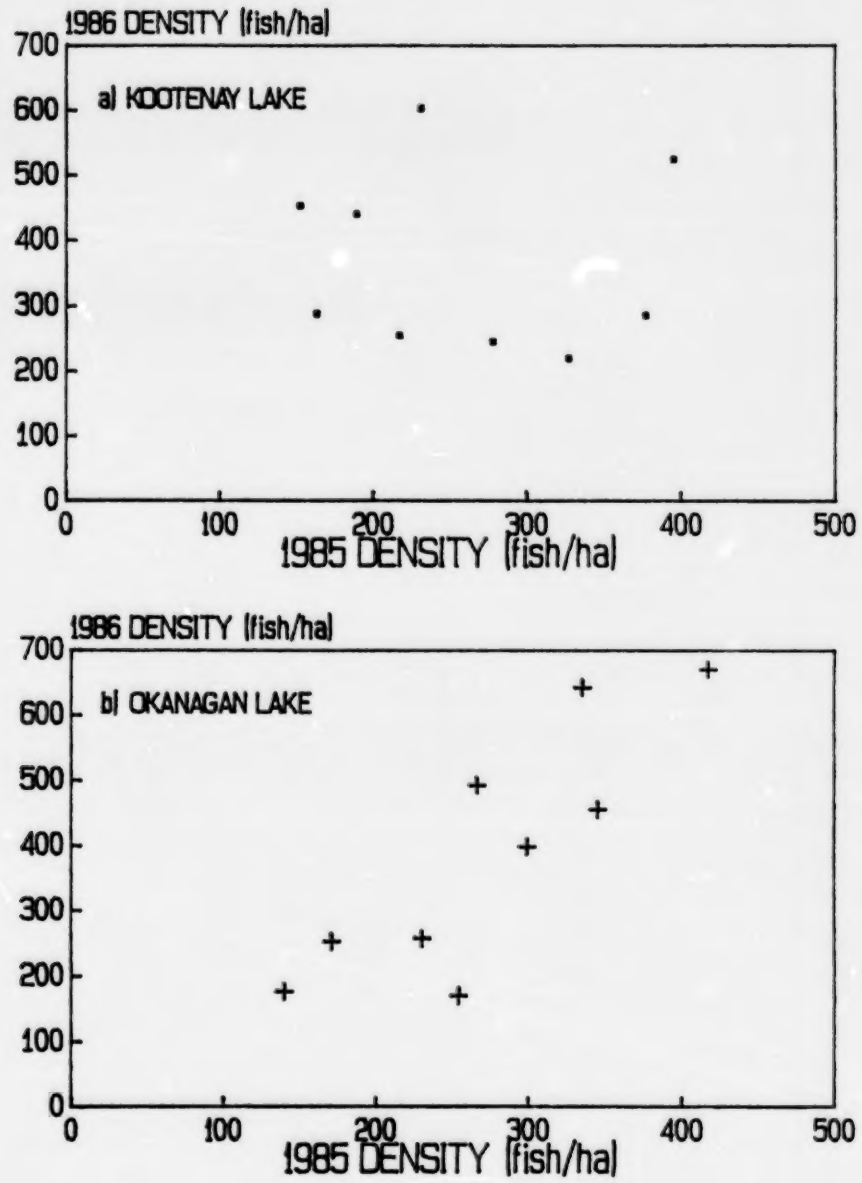

Figure 11. Relationship between fish densities measured by echosounder on transects in 1985 and fish densities measured on the same transects in 1986.

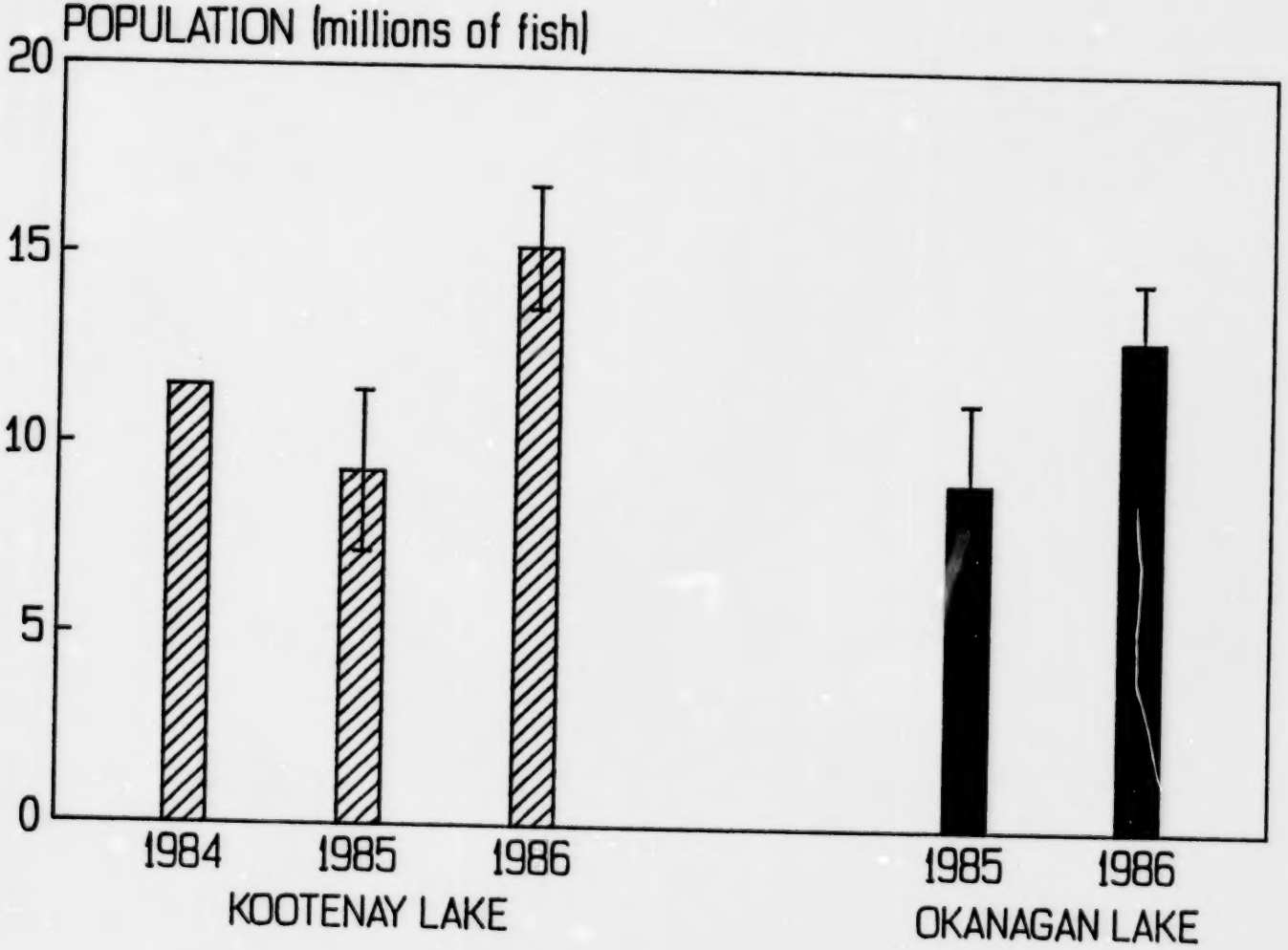

Figure 12. Total kokanee populations in Kootenay and Okanagan lakes. Range bars are ± 2 S.E.

Both the trawl sampling and the echosounding can be done during a 5- to 10-day period in the fall. This is the best time of year for echosounding and trawl CPUE estimates because fry are more vulnerable to the sampling gear, all age classes are confined below the thermocline at night and kokanee are more uniformly distributed than at other times. Spring is a better time to index growth but samples have proven difficult to obtain in the spring and date standardization should correct for the rapid fall growth rates of smaller fish.

In the absence of survival data, a population index is the logical complement to growth data. As with growth, managers find it difficult to associate changes in population size with specific factors, but population densities, mediated by survival, are the second major way that fish respond to both deterioration and improvement in their rearing environment.

List of previous Fisheries Technical Circulars

1986 75 Tsumura, K. and J.M.B. Hume. A comparison of precociousness in three graded size classes of hatchery-reared rainbow trout (Salmo gairdneri).

1987 76 Billings, S.J. Steelhead harvest analysis, 1985-86.

1987 77 Hooton, R.S., B.R. Ward, V.A. Lewynsky, M.G. Lirette and A.R. Facchin. Age and growth of steelhead in Vancouver Island populations.

1987 78 Ashley, K. Artificial circulation in British Columbia: Review and evaluation.

1987 79 Stone, Michael. British Columbia freshwater results of the 1985 National Survey of Sport Fishing.

1988 80 K. Tsumura and V. Blann. Fishery development in barren, wintekill lakes.

1988 81 Billings, S. Steelhead harvest analysis, 1986-87.

1988 82 Lirette, M.G. and R.S. Hooton. Telemetric investigations of winter steelhead in the Salmon River, Vancouver Island, 1986.

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1988 90 Johnston, N.T., C.J. Perrin, H.A. Andrusak and E.A. Parkinson. The early growth of kokanee (Oncorhynchus nerka) fry in relation to ration.

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1988 92 Lirette, M.G. & R.S. Hooton. Coded-wire tag recoveries from Vancouver Island sport caught steelhead, 1982-86.